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PHYTOPATHOLOGY

VOLUME IX NUMBER 7

JULY, 1919

COTYLEDON INFECTION OF CABBAGE SEEDLINGS BY PSEUDOMONAS CAMPESTRIS[1]

CHARLES DRECHSLER

WITH SIX FIGURES IN THE TEXT

That the bacterial black rot of crucifers attacks seedlings more rapidly as well as with more destructive effects than older plants has been noted by several investigators. Smith (2) reports that "When the cabbage is attacked early in the season and severely, it is either destroyed outright in the course of a few weeks, or is so injured that no head forms." And Brenner's (1) observations are particularly pertinent:

"Although cabbage is susceptible to infection with *Pseudomonas*, younger plants, especially seedlings, are destroyed with greater rapidity and certainty than older specimens. Even after eight days the cotyledons show typical symptoms of the disease, which with the increasing growth of the plant, spreads quickly to the first leaves, leading either to complete destruction, or at least to malformation."

Brenner makes no mention of the manner in which the cotyledons of his seedlings became infected; but presumably the young plants were inoculated by needle punctures. It has long been known that outside of wounds the black rot organism gains entrance into older plants by way of the specialized water-pores that occupy serratures on the margins of the leaves. The cabbage seedling, however, does not unfold its first true leaf until a week or more after coming up; and as the cotyledons are devoid of specialized hydathodes, the question arises whether the parasite enters the young unwounded seedling through its roots, or through its stem or cotyledons by a channel not hitherto recorded for this disease.

To solve this question cabbage seeds were planted in greenhouse soil heavily infested with the black rot organism. Over three hundred pots were used in the experiment, each pot being sterilized in the autoclave and

[1] An abstract of this paper appeared in Phytopathology, **4**: 401. D., 1914.

treated with the washings of approximately fifteen grams of steamed potato media thoroughly covered with the yellow slimy growth of the parasite. The pots were kept moderately moist. Germination of the seeds was normal, the young seedlings showing vigorous growth. From twelve to twenty days after planting, the margins of the cotyledons became blackened, the discoloration appearing as a black line extending along the sinus, but never beyond it. A day or two later the affected cotyledons showed a dull streaking toward the center, associated with pronounced symptoms of wilting (fig. 1c); and in another day they had completely collapsed (fig. 1b). In this shriveled condition the cotyledons may remain attached to the stem until the latter also collapses and shrivels. In cases where the first symptoms on the cotyledons appear after one or two leaves have been unfolded (fig. 1d), the lower leaf shows the characteristic dull black streaks and wilts one to three days after the collapse of the cotyledons; and when in one to two days more the younger leaves and the terminal bud become affected, the destruction of the plant is achieved.

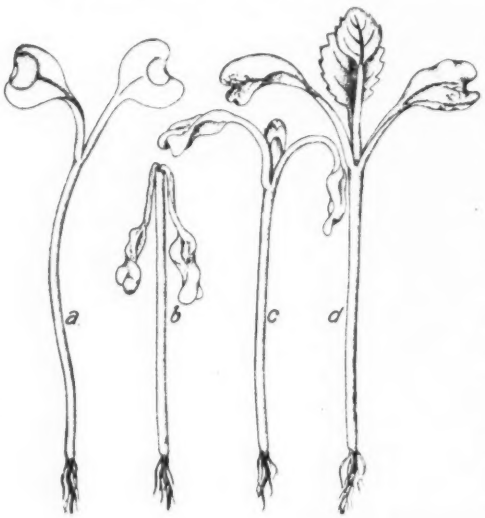

FIG. 1. *a*. Healthy seedling with extruded droplets of water adhering along sinuses of cotyledons. *b*. Diseased seedling in advanced stage of collapse. *c*. Seedling with cotyledons infected and wilted. *d*. Somewhat older seedling with cotyledons beginning to wilt.

A large number of diseased seedlings were examined, and in each case the infection was found to originate at the margin of the sinus of the cotyledon. When material showing very early stages of infection, especially before any macroscopic symptoms were observable, was treated with alcohol to remove the chlorophyll, and the cotyledons examined *in toto* under the microscope, the regions of incipient infection could readily be made out as dark areas always associated with a stoma (fig. 2). Stomata on the edge of the sinus appeared particularly subject to invasion (fig. 3), although numerous substomatal accumulations of bacteria were found near the upper epidermis some distance, usually not exceeding 0.5 mm., back of the sinus.

The progress of the invading bacteria can readily be followed in microtome sections stained with carbol-fuchsin and orange-G; and it differs in

FIG. 2. CABBAGE COTYLEDON SHOWING SIX CENTERS OF INVASION

a b and *f* involving stomata on edge of sinus; *c d* and *e*, stomata back of edge on upper surface

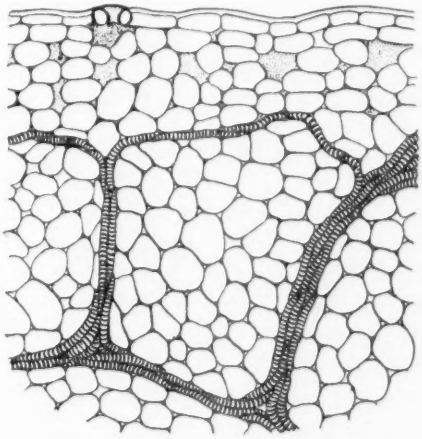

FIG. 3. MEDIAN OPTICAL SECTION OF INFECTED COTYLEDON IN PLANE OF SURFACE, SHOWING BACTERIA ENTERING STOMA *a* IN FIGURE 2

no essential features from the history of water-pore invasions in older plants as described by Smith (3). As a considerable number of stomata are usually invaded, the parasite in spreading from substomatal cavities into the surrounding parenchyma, brings about the coalescence of many centers of infection before a vessel is reached and the disease becomes systemic. The result is that the marginal tissue is usually disrupted along the greater extent of the sinus (fig. 4), yielding the characteristic charring of the edge that constitutes the first macroscopic symptom.

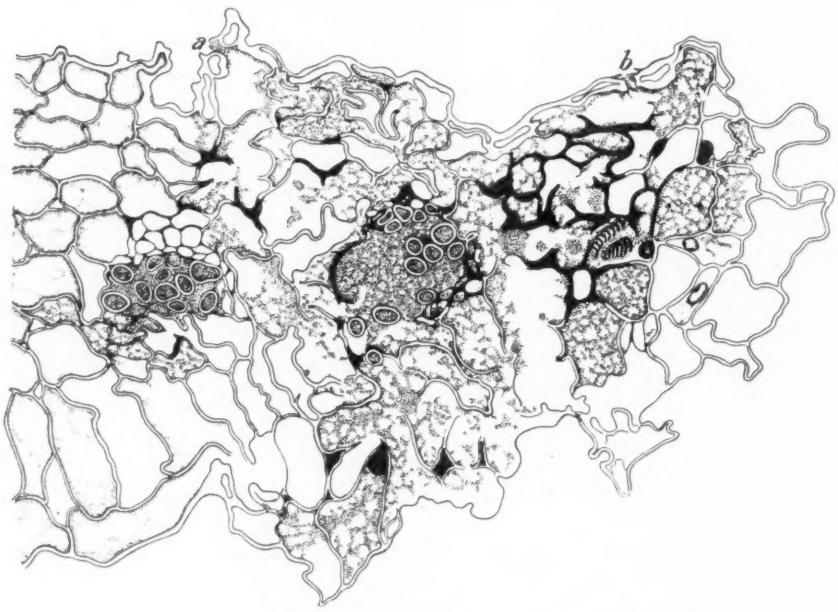

FIG. 4. LONGITUDINAL SECTION OF INFECTED COTYLEDON SHOWING TISSUE IN MARGINAL ZONE ENTIRELY DISRUPTED; AND TWO INVADED STOMATA ON UPPER SURFACE AT POINTS *a* AND *b*

In the stem, the parasite effects its maximum destruction near the attachment of the cotyledons. Cavities develop much more rapidly here than anywhere in older plants, apparently owing to the soft condition of the tissues, and the absence of gaps in the cylindrical stele. Even in seedlings which have merely commenced to wilt (fig. 1c) only a small proportion of xylem elements may be left intact; and a day later when the cotyledons have collapsed, practically all the remaining vessels may be involved in cavities, or occupied by bacteria.

In sections farther down the stem, the cavities become smaller and finally become completely resolved into a number of invaded vessels; and the

invasion of some of these vessels may usually be followed into the upper portions of the root. The decrease in the extent of distribution of the organism downward becomes evident in a comparison of figures 5 and 6, repre-

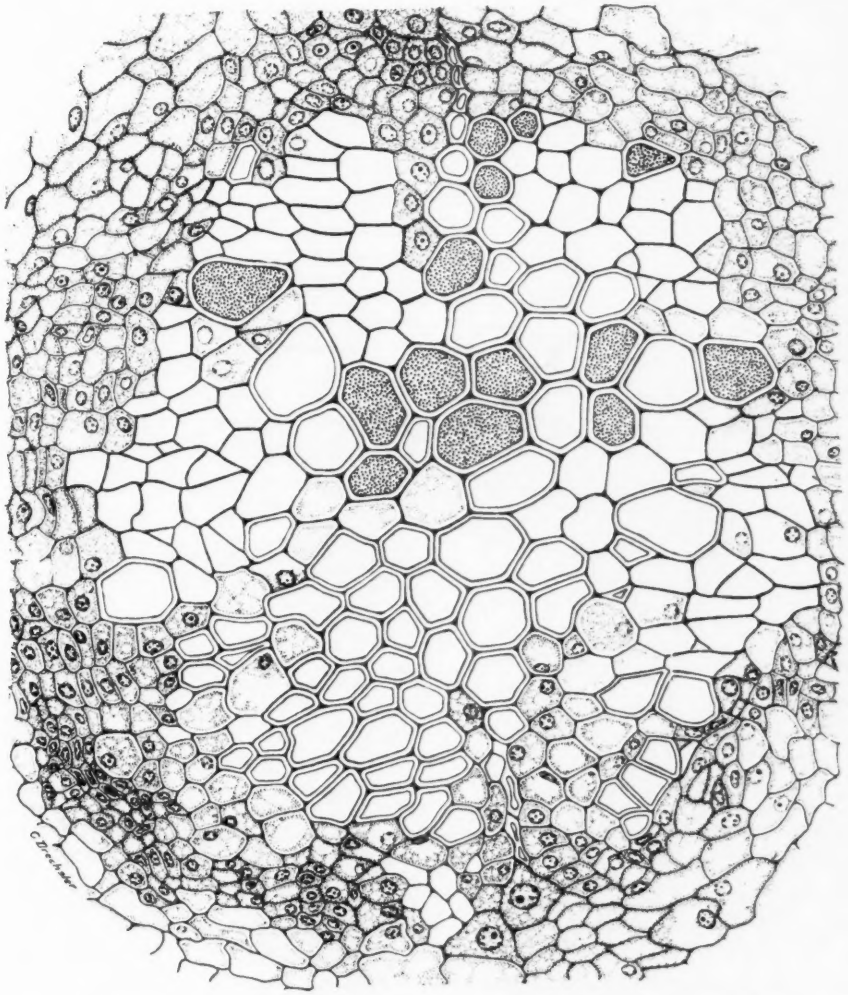

FIG. 5. CROSS-SECTION OF STEM NEAR ATTACHMENT OF DISEASED COTYLEDONS
Most of the xylem elements occupied by bacteria or involved in cavities.

senting conditions found in the same plant in the upper parts of the stem and of the root respectively. In this connection it may be mentioned that although Stewart and Harding (4) believed that the disease can be com-

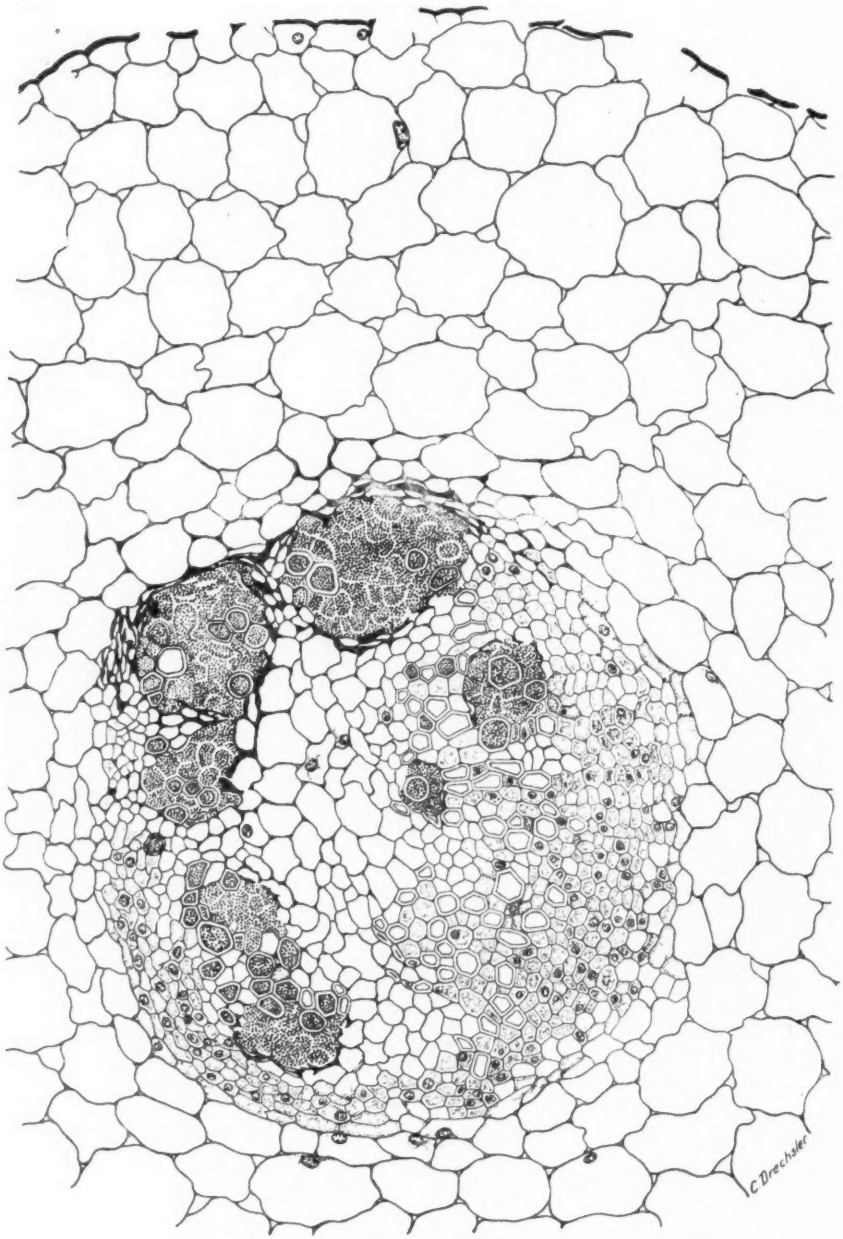

FIG. 6. CROSS-SECTION OF ROOT OF DISEASED CABBAGE SEEDLING USED FOR FIGURE 5, IMMEDIATELY ABOVE ATTACHMENT OF UPPERMOST BRANCH ROOT

Bacterial invasion confined to individual vessels; adjacent cells entirely normal

municated through the root systems, and Smith (2) regarded such a mode of entry as not unlikely in the earlier stages of growth, bacteria could be detected only in the upper portions of seedling roots. And in no case was there any reason to believe that infection had started at the roots, the negative evidence here being in harmony with the observations made on older plants.

The seedling furnishes unusually good material for observations on the possible effects of bacteria on actively functional cells. In every section of the stem numerous vessels plugged with bacteria, may be found adjacent to meristematic cells, parenchymatous cells, or xylem elements in which the nucleus and cytoplasm show no evidence of degeneration. The absence of any signs of injury in such cells as long as the walls remain intact and the cell is not involved in a cavity, is convincing proof that the parasite does not secrete any soluble toxic substance capable of diffusing even very moderate distances.

Since infection through the water pores is dependent upon guttation, it was suspected that perhaps a similar relation might obtain in the case of cotyledons. Accordingly, very young seedlings were placed in a moist chamber where abundant extrusion of water took place within twelve hours. The droplets always appeared at some point along the sinus, adhering either to the reentrant edge or to the upper surface close to this edge—never to the lateral margins or to the central portions of the cotyledons. When these droplets were inoculated by cautiously adding about an equal volume of a suspension of *Pseudomonas campestris*, and the seedlings kept in the damp chamber twelve hours longer, the same symptoms were induced in ten to sixteen days as had been observed in the seedlings grown in the heavily inoculated soil. Over one hundred seedlings were used, and of this number over three-fourths were killed within twenty days after inoculation, the first symptoms always appearing in the region active in guttation, embracing the marginal tissue along the sinus.

A comparison of invaded stomata as well as healthy stomata in the guttating region with those elsewhere situated, has not revealed any morphological differentiation. Probably the former possess merely a miscellaneous capacity to function in the absence of more specialized structures. The physical basis of such localization might be sought, for example, in a possible difference in mechanical response of the guard cells to external conditions; or perhaps, in peculiarities in the nature and disposition of the conducting tissues. As the seedlings grow older, and particularly as the hydathodes of the first true leaves become functional, the amount of water extruded by the cotyledons is, as a rule, greatly reduced; and the possi-

bilities of natural cotyledon infection are reduced in a corresponding measure.

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BRIEFER ARTICLES

THE WHEAT NEMATODE, *TYLENCHUS TRITICI*, ATTACKING RYE, OATS, SPELT, AND EMMER

With Plate XVIII

L. P. Byars, A. G. Johnson and R. W. Leukel

In following up the work on the eelworm disease of wheat, caused by the nematode, *Tylenchus tritici*, an experimental plot was planned and planted in the fall of 1918 on the Arlington Farm of the United States Department of Agriculture at Arlington, Virginia. In this plot rye, barley, oats, spelt and emmer were planted, as well as a number of varieties of wheat. This plot was designed to throw light on a number of phases of the problem but the particular phase upon which important definite results are already at hand is in regard to the host range of the parasite.

In seeding the rye (*Secale cereale*), barley (*Hordeum vulgare*), oats (*Avena sativa*), spelt (*Triticum spelta*) and emmer (*Triticum dicoccum*), and most of the wheat, viable larvae of the wheat nematodes, in some cases free in water and in other cases normally enclosed within the galls, were sprinkled or strewn with the seed when sown. The plot has been kept under continuous observation and not only are there abundant infections on the wheat varieties, where there is evidence of some variations between different varieties, but there are also abundant infections on rye. The virulence of the attack on rye is very marked. The infections on rye as on wheat show conspicuous leaf and stem symptoms as well as head symptoms. The infected rye plants show marked, abnormal curling and distortion of the leaf-blades and not uncommonly distortions of the stem. The infected rye heads (Plate XVIII, *A*, *C*) not only show conspicuous gall formation in the essential organs of the flowers and florets, but definite galls have been noted also in the tissues of some of the lemmas and paleas of the rye flowers (plate XVIII, *E*, *F*). In addition to its attacks on rye, some definite nematode infections have been found on oats, spelt an emmer at the Arlington Farm referred to above. On the latter crops, leaf, stem, and head symptoms somewhat similar to those on rye and wheat were observed.

While Marcinowski[1] states that the wheat nematode attacks rye, oats and spelt to a minor extent in Europe, this, so far as the writers are aware,

[1] Marcinowski, K. Parasitisch und semiparasitisch an Pflanzen lebende Nematoden. Arbeiten aus der Kaiserlichen Biologischen Anstalt für Land-und Forstwirtschaft **7**: No. 1, 67–116. 1909.

is the first record of its occurrence in this country. Likewise, so far as known, the parasite has not been previously reported on emmer.

No nematode infections have as yet been noted by the writers on barley.

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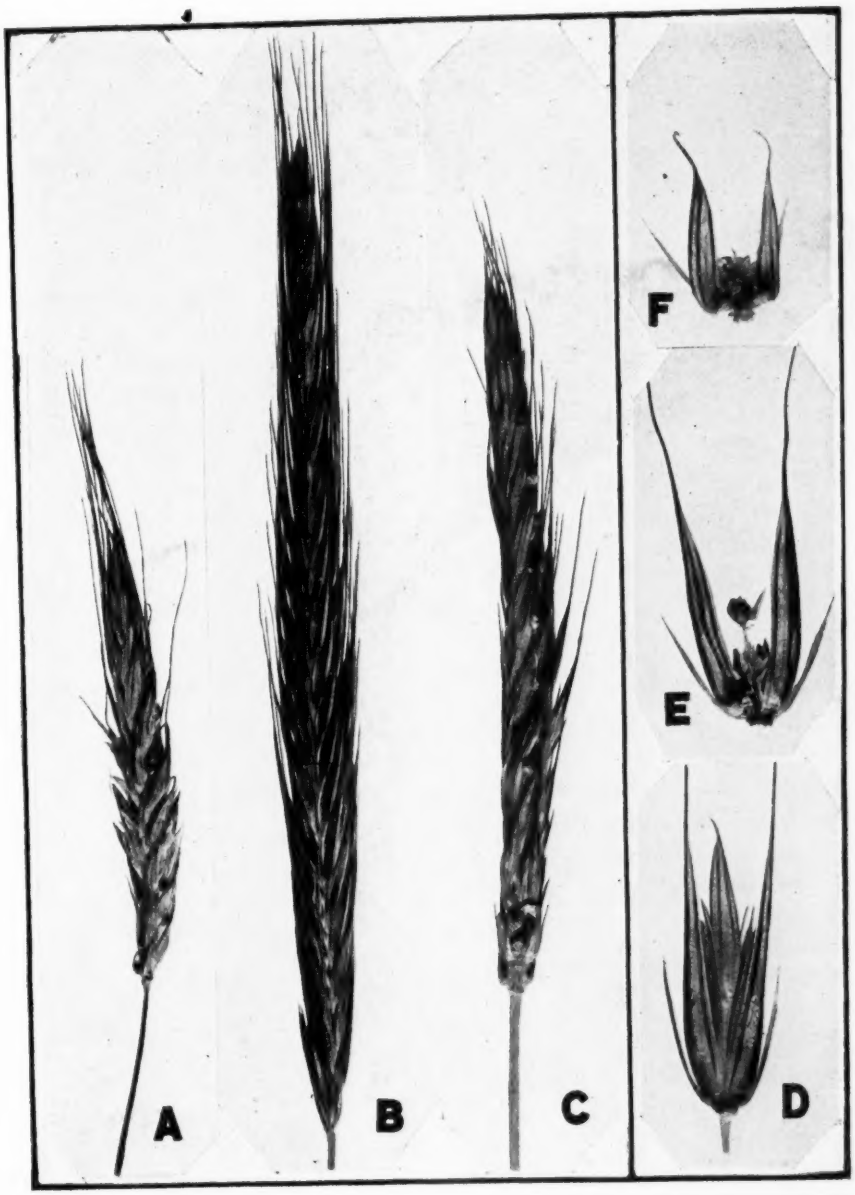
PLATE XVIII

A normal head or spike of rye (*B*) between two nematode infected heads (*A* and *C*) photographed natural size, and rye spikelets (*D–F*) magnified about twice. Compare the normal spikelet (*D*) with the infected spikelets (*E* and *F*) which contain nematode galls.



BYARS, JOHNSON AND LEUKEL: WHEAT NEMATODE

STUDIES ON THE VIABILITY OF THE POTATO BLACKLEG ORGANISM

GLEN B. RAMSEY

During the seasons of 1916 and 1917, the writer spent considerable time in studying the blackleg disease of potatoes as it occurs in Aroostook County, Maine. The experiments described below, were performed to supplement in a minor way, the results of extensive field observations and experiments.

ENDURANCE OF LOW TEMPERATURES

To get data regarding the ability of the blackleg organism to withstand low temperatures within infected tubers, healthy disinfected potato tubers were inoculated by means of a hypodermic needle with a pure culture of a strain of *Bacillus atrosepticus* Van Hall. The tubers were placed in a moist chamber and allowed to remain there at room temperature for forty-eight hours. All of them at the end of this time showed a marked rot at the point of inoculation. These potatoes were then packed in cracked ice and placed in the refrigerator where the temperature registered 0°C. or only a fraction above during the entire experiment. Every twenty-four hours one of these tubers was taken out and dilution plates made from a portion of the decaying pulp, then the tuber was planted in sterilized soil in the greenhouse.

What appeared to be characteristic colonies of the blackleg organism were found in all plates. These plates can only be regarded as indicators, however, for since the experiment was devised to study the viability of the organism within the tubers, as shown by planting such tubers, these reisolated bacteria were not again tested for pathogenicity. After the tubers had been on the ice for 168 hours the plates showed that the number and activity of the bacteria had decreased considerably. At the end of eleven days, or after the last tuber had been subjected to a temperature of approximately 0°C. for 264 consecutive hours, the plates from this tuber still showed bacterial growth, but it was reduced to a minimum.

Two tubers germinated and sent up sprouts which reached a height of about 2 inches but they died down immediately with blackleg. These sprouts came from the tubers which had been on ice for 72 and 96 hours respectively, all other tubers decayed without showing any sprouts above ground. This may explain why blackleg is never found in volunteer plants in Maine. Morse (1) says, "On fields which are planted with potatoes the second time in succession there is usually quite a percentage of volunteer plants which spring up from tubers which remained in the soil over winter. The writer has never seen such plants affected by blackleg.

This observation was quite unexpected, for it seems not unreasonable that, if the tubers were sufficiently protected from the frost to be able to germinate, the bacteria causing the disease might live over in the soil in such infected tubers as well as in storage."

Evidently the infected tubers which remain buried in the fields at digging time, decay to such an extent that they are unable to germinate, or if they do germinate the sprouts are immediately killed by the organism. Therefore, all volunteer plants which make their appearance in the spring are free from blackleg.

In order to test whether there were living blackleg bacteria in the soil or in the decayed tubers capable of infecting a new crop, healthy potatoes of the Early Rose variety were halved and one piece was placed in each pot, in direct contact with the decayed remains of the inoculated tuber. This new planting was made just one month after the first. All of the Early Rose tubers produced vigorous plants which matured without showing any signs of blackleg whatever. These results agree in every way with a somewhat similar experiment upon a larger scale conducted by the writer and a co-worker (2) for two years at Presque Isle, Maine. All results tend to show that the blackleg organism does not live in tubers that may overwinter in the soil and remain capable of infecting a new crop.

SOIL INOCULATION

In order to further our knowledge regarding the ability of the blackleg organism to overwinter in the soil of Aroostook County, Maine, duplicate samples of three soil types were collected in the fall of 1916. Small glass jars with a capacity of about one-half pint were filled with the soil and then 15 cc. of a virulent culture of *Bacillus atrosepticus* was poured into the top of each jar. The covers were then tightly screwed down and one set of samples was buried out of doors at a depth of 5 inches, while the other set was placed on a side wall in a basement where there was no artificial heat.

The following May both sets of jars were inspected and found to be in good condition. Several series of dilution plates were made from these samples and all favorable looking colonies were tested for pathogenicity upon cut slices of potato tuber. Authentic cultures of the blackleg organism were also tested as a check with each trial of an unknown. The blackleg culture always produced the typical rot of the tuber, but of the many strains of bacteria obtained from the soil which had over-wintered in the field, as well as those from the soil kept in the basement, not one was found capable of producing the blackleg rot.

ATTEMPTED INOCULATION OF PLANTS BY A WATERING METHOD

In one or two instances on rare occasions there have been some indications that a blackleg plant situated in a low moist area may transmit the disease to the surrounding plants, the theory being that during a heavy rain the bacteria from the infected plant are washed to the neighboring plants, thus spreading the disease. To ascertain the possibility of young, healthy potato plants contracting blackleg from neighboring diseased hills, the following experiment was devised. Thirty-three 12-inch pots were planted in the soil so that their tops were flush with the level of the surrounding ground. Eleven of these pots were filled with the best Aroostook potato soil, Caribou loam (diagram 1), eleven with a gray second class soil, Washburn loam, and eleven with a black muck that is found in the marshy regions. One pot of each type was sterilized, while all the others were allowed to remain just as the soil was taken out of the field. Healthy disinfected Irish Cobblers were cut and planted in each pot. Two weeks after planting, portions of a decayed tuber that had been inoculated with

Diagram 1

	LOT					
	1	2	3	4	5	6
Caribou loam. Type I.....	0	0 0 0	0 0	0	0 0 0	0
Washburn loam. Type II.....	0	0 0 0	0 0	0	0 0 0	0
Black muck. Type III.....	0	0 0 0	0 0	0	0 0 0	0

blackleg were incorporated in the soil of three pots (lot 1). To conserve the moisture as much as possible, nine of the pots (lot 2) were covered with oil-cloth, leaving a small hole in the center for the stem of each plant. Each of these was watered with 50 cc. of a forty-eight hour culture of *Bacillus atrosepticus* which had been diluted to 200 cc. with tap water. Six pots (lot 3) were treated in the same way but not covered. Three pots (lot 4) were treated with the culture dilution mentioned above, after first killing the bacteria in the culture by heating. A fifth group (lot 5) of nine pots was given 200 cc. of tap water. The last three pots (lot 6) were treated the same as (lot 3), the only difference being that these pots contained sterilized soil. This watering treatment was begun when the plants were about 4 inches tall, and was continued each week for seven successive weeks.

During the growing season only one plant died down with blackleg and that plant was in one of the pots which had received part of the inoculated tuber in its seed bed. At harvest time, there were 8 tubers that showed stem-end rot, and 10 others showing decay. It is doubtful how much, if any, of the decay was due to blackleg. In the writer's opinion, however

tuber infection was made possible because of injury to the roots and stolons when samples of soil were taken in order to get the relative moisture rontent of the soil types. There were no above ground parts affected with blackleg where the watering method was used.

The above experiment with certain variations was practically duplicated in 1917. Twenty-eight pots (diagram 2) of two soil types were used. The pots were divided up into seven lots of four each. Lot number one was left untreated as a check receiving nothing but tap water. The other six were watered, each lot in succession at one week intervals, with 50 cc. of a forty-eight hour culture of the blackleg organism which had been dilated to 300 cc. with tap water. The second lot was watered with the diluted culture just as the plants were breaking through the soil. The third lot was treated in the same way one week after the second, the fourth one week after the third, etc. This plan was followed in order to study the susceptibility of the plants at various ages. The last lot treatment was made when the plants were 12 inches high.

Diagram 2

	LOT													
	1		2		3		4		5		6		7	
Caribou loam. Type I.....	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Washburn loam. Type II.....	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Extreme care was taken to prevent wounding the root system or stems of these plants. The treatments were made late in the afternoon so that the diluted culture would have plenty of time to soak into the soil before the sun came out the following morning and killed the bacteria at or near the surface.

All plants were healthy during the growing season and at harvest time all tubers were found to be free from rot. These two experiments tend to show that unless the seed piece is infected at planting time, there is little chance that uninjured plants will contract the disease even though the causal organism is washed about the stem and root system.

MAINE AGRICULTURAL EXPERIMENT STATION
ORONO, MAINE

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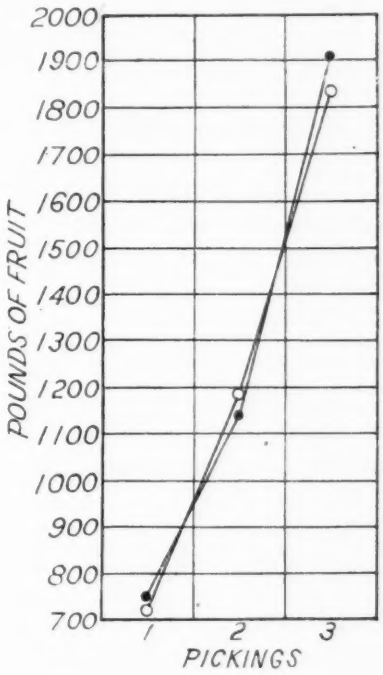
EFFECT OF SPRAYING ON EARLY RIPENING OF TOMATO FRUIT

FRED J. PRITCHARD AND W. B. CLARK

Spraying has not delayed ripening of tomatoes in experiments carried on coöperatively the past three years by the United States Department of Agriculture and state experiment stations in Maryland, New Jersey, Indiana and Virginia.



EFFECT OF SPRAYING ON YIELD OF EARLY FRUIT

Dots indicate yield of sprayed plots; circles, yield of unsprayed, or check plots

Tomatoes defoliated by leaf spot present, in their dead leaves and exposed fruit, a premature appearance which makes a striking contrast with the normal appearance of green foliage and obscured fruit of sprayed plants, but this difference is not proof of altered maturity. If early ripening were brought about by defoliation, the preservation of the foliage by spraying would, under conditions favorable for the development of leaf spot, delay the maturity of the crop. Some data recently published by Edgerton in Louisiana Bulletin 164 undoubtedly show delayed ripening in two sprayed plots (fig. 2) but these results are not confirmed by data from his other sprayed plots (figs. 1 and 3) in which the only change

was either an increase or decrease in total yield. It is therefore possible that the delay shown in his figure 2 was caused by soil variations.

Delayed ripening of tomatoes would reduce profits from growing fruit for early market, delay delivery of fruit to canneries, and increase loss of fruit by frost. No treatment causing these effects should be recommended unless its profits outweigh its losses. It is therefore important to determine the effect of spraying on the maturity of the tomato crop. Growers have been informed of the improvement in yield and quality of fruit from spraying but have not been given much information regarding its effect on ripening of fruit. In fact not all pathologists hold the same opinion on this matter.

If spraying delayed early ripening it would reduce yields of fruit in the first few pickings. Unsprayed plots would therefore outyield sprayed plots in the early part of the picking season. The effect actually produced in 14 fields in which 133 plots were sprayed and 54 were unsprayed may be seen in the following table. In each experiment the sprayed plot was the same size as the check plot.

Effect of spraying on early ripening of tomato fruit

AVERAGE NUMBER OF POUNDS OF FRUIT PER PLOT						NUMBER OF PLOTS		NUMBER OF APPLICATIONS DURING SEASON	LOCALITY	YEAR
1 picking		2 picking		3 picking						
Sprayed	Check	Sprayed	Check	Sprayed	Check	Sprayed	Check			
500	360	1440	1150	610	590	21	12	4	*Salem, N. J.	1916
928	923	1258	1007	1445	1536	20	4	7	Riverton, N. J.	1917
250	273	244	285	435	430	10	6	3	Riverton, N. J.	1917
83	101	360	388	133	159	12	7	6	Riverton, N. J.	1917
30	17	192	133	1050	733	4	1	3	Hurlock, Md.	1917
233	200	356	533	733	600	3	1	4	Hurlock, Md.	1917
102	33	840	767	2293	2067	5	1	3	Hurlock, Md.	1917
150	133	325	433	483	400	4	1	4	Hurlock, Md.	1917
68	63	170	250	1000	1233	9	2	4	Hurlock, Md.	1917
7	27	40	62	114	159	6	2	4	Hurlock, Md.	1917
2048	1874	1431	1431	4114	3908	12	5	7	Riverton, N. J.	1918
467	567	2267	2967	2800	3300	6	3	5	Hurlock, Md.	1918
278	210	796	636	390	246	10	4	3	Salem, Va.	1918
106	155	409	364	759	540	11	5	3	Paoli, Ind.	1918

* The original records on separate pickings in this experiment are not in possession of the writers. The figures used are estimates made from a graph used in N. J. Annual Rept. 27, for the year 1916 by W. H. Martin who carried on the work under direction of the Office of Cotton, Truck, and Forage Crop Disease Investigations of the United States Department of Agriculture and the Department of Plant Pathology of the New Jersey Agricultural Experiment Station.

No consistent effect of spraying on early ripening is shown in the table. The differences in yield between sprayed and unsprayed plots extend in both directions and appear no larger than those which are ordinarily produced by variations in soil fertility, drainage, etc. Therefore they are fluctuations caused by inequalities of the soil and have no relation to spraying.

A summary of the foregoing results based on average yield of fruit an acre from sprayed and from unsprayed plots is presented in the following graph.

The average yield of early fruit is somewhat higher from the sprayed plots than from the unsprayed plots but the differences are not significant. Therefore spraying in these localities does not seem to affect early maturity of tomato fruit.

BUREAU OF PLANT INDUSTRY
U. S. DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

THE POTATO LEAFHOPPER AND THE HOPPERBURN[1]

E. D. BALL

During the past season (1918) potato foliage was severely burned over an area extending from Montana and Kansas to New York and New Jersey. The writer's attention was called to this condition in Wisconsin in July and an examination disclosed the fact that the partly burned leaves had one or more nymphs of the potato leafhopper on the under side while the younger leaves that were still fresh and green showed no trace of them.

The potato leafhopper (*Empoasca mali* LeB.), a minute green insect that hibernates as an adult, flies to the potato fields soon after the plants appear and lays its eggs in the midribs or leaf stems of the partly grown leaves. These eggs hatch in a week or two, depending on the weather, and the little green nymphs appear on the under side of the leaves, usually staying on a single leaf until full grown unless seriously disturbed. During their growth they shed five white skins which remain attached to the under side of the leaf. The size and number of these cast skins on a leaf is therefore a fair index of how many leafhoppers have fed there or how long a single one has fed. The eggs are minute, elongated, transparent bodies, very difficult to detect when fresh. At about the time the eggs hatch the slits into which they were thrust begin to expand and continue to do so for some time afterwards, finally becoming quite marked longitudinal scars, often seriously distorting the midribs.

[1] For extended discussion and bibliography, see Second Biennial Report of State Entomologist, Wisconsin, 1919.

At the time the fields were first examined, many of the early potato plants were dead, others had many dead leaves, while still others had green leaves on top and burned ones below. The dead leaves showed the egg scars and cast skins in abundance, leaving no doubt that they had been infested with the leafhoppers until they burned up and died. Careful search was made but no burned leaves were found that did not have either nymphs, cast skins or egg scars, while on the other hand, no green leaves were found that showed any one of the three. Fields were examined in Wisconsin, Minnesota, Iowa, Illinois and samples were received from Michigan (Coons) and Ohio (Selby and Babcock) all of which showed the same condition. Examples from France (via Coons) were in bad condition and very doubtful.

Cage experiments in which a large number of adult leafhoppers were placed on a half grown plant produced a bad burning and rolling of the leaves in three days. Cages were placed over two more plants and kept on for three weeks. The plant on which a large number of leafhoppers were placed died down. All leafhoppers were removed from the other plant before caging. This plant increased one-third in size and put out beautiful broad green leaves with no sign of burning, although it was a hot dry time in August. The plants in the field had a moderate number of leafhoppers. They grew very little during the three weeks and burning continued to increase over the tops.

Early potatoes or rather potatoes planted early, were most seriously injured because the leafhoppers were flying when the earliest potatoes came up, and the eggs were deposited upon them. Potatoes coming up a few weeks later, after most of the eggs were deposited, were practically free from injury until the second brood appeared in late July or August. The burning appeared first on leaves below the top because the eggs took some time to hatch and new leaves without eggs were pushing out on top all the time.

The number of leafhoppers necessary to kill a plant was not determined by experiment but apparently one was able to burn a leaf while two or more to each leaf killed the plant.

Burning was by rows and varieties and not according to exposure to sun or varying with soil conditions. Leaves shaded beneath another plant were frequently burned. Burning had little reference to temperature; the temperature in southern Wisconsin was, in fact, below normal until after the early potatoes all burned.

Dahlias and box-elder trees are attacked by the same leafhopper and burned in the same way. They show the egg scars and cast skins as in the case of the potato. Water sprouts of apples, nursery stock, and fast growing raspberry canes are attacked, the leaves curled downwards and the tips burned.

The hopper burn often extends in on the veinlets nearly to the midribs when only the outer half of the leaf is burned. Apparently the little leaf hoppers puncture these veinlets and cause them to collapse, after which the marginal burn appears. A favorite place for egg deposition appears to be in the midrib just back of the tip. When the eggs hatch the veins appear to burst or collapse and cause the burning of a triangle at the tip of the leaf.

That insects might be one of the causes of burning of potato leaves was long ago suggested by Dr. L. R. Jones, then working in Vermont. Professor Parrott of Geneva, N. Y., records a very widespread outbreak of potato leafhoppers in New York and a very destructive outbreak of tip-burn occurring at the same time. Several other parallel occurrences could be cited. Tip-burn has been used as a general name for burning of potato foliage regardless of cause. Hopperburn is proposed (at the suggestion of the pathologists) as the name of the specific effect of the injury by the leafhopper. The observations of 1918 indicated that nearly all of the burning of that season was associated with the leafhopper.

Hopperburn is apparently specific, that is, caused by a single species of leafhopper. Other closely related leafhoppers produce a characteristic white-spotting of leaves with no burning at all. Curly-leaf of beets was the first strictly insect-transmitted plant disease discovered, hopperburn appears to be another, but it does not appear to spread from one part of the plant to another as in the case of curly-leaf and must therefore be quite different in nature. The whole subject of insect relation to plant disease, the nature of the active agent transmitted, as well as the reaction of the plant tissues to these agents, offers a most fruitful field for research as well as a pressing invitation for more hearty coöperation between pathologists and entomologists.

Spraying with Bordeaux mixture has long been known to reduce the amount of tip-burn. It has also been shown that it acts as a partial repellant for the leafhoppers which probably explains the former results. The most effective control of the leafhoppers was obtained with Black Leaf 40 used not weaker than 1 to 800 with 5 parts of soap. This must be applied from the under side of the leaves. Early in the season this is easily done by the use of extension angles ($\frac{1}{2}$ inch gas pipe bent into a crook). Four-row spray booms can be equipped with these. Late in the season when the vines are tangled they are best sprayed by drawing them over with a 6-inch board drawn about 18 inches in front of the nozzles which are set at an angle so that they hit the plants as they are drawn over and again as they snap back.

IOWA AGRICULTURAL COLLEGE
AMES, IOWA

A METHOD OF STEAM STERILIZATION OF SOIL FOR CONTROLLING NEMATODES[1]

LEO E. MELCHERS

It has been common experience, when attempting to control nematodes by the steam sterilization of the soil, that it is frequently impossible to secure sufficient pressure in the greenhouse boiler for the common harrow or inverted pan types of sterilizers. When the pressure is 50 to 60 pounds or less at the boiler and it is necessary to carry the steam a considerable distance in the greenhouse, condensation takes place. As a result, these sterilizers cause puddling of the soil and otherside do ineffective work. In our experiments, all modifications of these types were equally unsatisfactory for low pressure. Therefore, a method which could utilize a low steam presure and still do satisfactory work without injury to the soil, seemed urgent, though it should be noted that where 80 pounds or more pressure is obtainable very good results may be obtained from the types on the market.

The method described herewith[2] was used in a span of fifteen greenhouses at Hutchinson, Kansas, which had the soil badly infested with nematodes (*Heterodera radicicola*). For two successive seasons previous to the treatment of the soil, the entire crops of tomatoes and cucumbers had been a total loss. After unsuccessfully trying out all styles of steam sterilizers, the apparatus described herein was devised and proved successful.

The necessary equipment for this device consists of 2 x 4's cut at suitable lengths, a few boards either as long, or half as long as the greenhouse is wide; canvas, burlap, sacking or a tarpaulin. This method has been devised purposely for greenhouses growing vegetables on the ground, although modifications of this method could be made to suit other conditions.

The first operation in carrying out the work consists of digging a pit at one end of the house to the depth that one wishes the soil sterilized. The width and length of the pits to be sterilized at one time depends somewhat upon the width of the greenhouse. In our work, the pits were dug 12 inches deep, 6 to 8 feet wide and 10 to 15 feet long. Two 2 x 4's are laid

[1] Published with the approval of the Director, Kansas Agricultural Experiment Station, as paper No. 31, contribution of the Laboratory of Plant Pathology, Department of Botany.

[2] This method as to its use, cost and efficiency, in the control of Damping Off of Coniferous Nursery Stock was given a thorough trial at this Institution in 1918, by C. A. Scott under the direction of L. E. Melchers, where it proved very successful in the nursery.

on edge in the bottom of the pit. These pieces should be the length of the pit and placed about 6 to 12 inches from the sides. One or two leads of steam pipes with T-outlets in the center, and at the ends, should be laid in between the two stringers (2 x 4's). The pipes can best be introduced from the ends or sides of the pits. It has been found more satisfactory to let the steam out through large openings rather than through perforations in the pipes. Pieces of 2 x 4's are then laid across the two stringers. They should be long enough to reach across the pit, and placed a quarter of an inch apart, to allow for the ascent of steam.

When the bottom has been laid, the soil which was removed may be thrown on to the platform formed by the 2 x 4 cross-pieces. Boards should be staked around the sides of the platform to retain the soil. The steam may then be turned on, thermometers placed in the soil and the entire pit covered with any covering that will retain the heat.

This method is much more satisfactory where low steam pressure has to be used, than one in which the steam is forced downward, as there is no puddling of soil, even at the lower pressures, yet 202°F. and slightly higher temperatures have been obtained when sterilizing 12 inches of soil. Each bed should be sterilized from one and one-half to two hours, depending on the steam pressure and the time necessary to obtain a temperature approaching 200°F. In our work we have felt that a temperature between 190 to 200°F. should be maintained for at least one-half hour. It should be remembered that a few inches of soil below the wooden platform is likewise sterilized in this process. It is extremely important that clods of soil are avoided in the beds being sterilized, for such masses of soil are not heated thoroughly enough to do efficient work.

After the first pit of soil has been sterilized, the skeleton platform is easily removed by means of an iron bar with a hook at the end for catching hold of the 2 x 4's and jerking them from underneath the soil. The platform should now be laid directly upon the soil just sterilized. When this framework has again been set and the steam pipes adjusted, the platform is ready for the second batch of soil which is dug immediately adjoining the soil which was just sterilized. In order to avoid extra labor, it becomes necessary to have one pit already dug just *ahead* of the bed being sterilized, so when the 2 x 4's are removed, they can be laid immediately in the pit which is ready for them. This is accomplished by erecting the *second bed on top of the first one*, i.e., on top of the first batch of soil sterilized.

When the second bed is ready for sterilization (*it is constructed directly on top of the one first sterilized*), one has a pit already dug to set the frame work in for the third batch. Thus a pit will always be in readiness for the frame work. It will be seen, that by this process, it becomes necessary to

return one batch of sterilized soil to the opposite end of the greenhouse after the whole house has been sterilized. This is the second batch which was sterilized and rests on top of the first. This cannot be avoided, but the soil can easily be carted back by means of wheel-barrows. In order to sterilize the soil surrounding and below the last pit at the opposite extremity of the greenhouse, the platform is constructed as usual in this pit and the extra pit-full of soil (the second batch sterilized) is carted back and thrown on to the frame work and resterilized. There is no occasion for contaminating the soil by following this scheme. One should always take all precautions, however, to avoid reinfecting the soil in a sterilized greenhouse through the workmen carrying contaminated soil on their shoes, the use of contaminated tools, bringing in unsterilized manure, etc.

Many greenhouses are irregularly constructed, with uprights and other obstructions more or less promiscuously scattered, which often makes the pan and harrow methods difficult to use. With the method just described, these obstructions are much less serious, since they can come in any part of the bed without hindrance to sterilization.

There is a little more expense connected with this method, on account of extra labor. It is not advocated as more economical, but rather as a means of sterilizing soils in situations that cannot be handled otherwise.

LABORATORY OF PLANT PATHOLOGY,
DEPARTMENT OF BOTANY
KANSAS AGRICULTURAL EXPERIMENT STATION

A NEW STEM-ROT AND WILT OF TOMATOES

R. E. STONE

WITH TWO FIGURES IN THE TEXT

In January, 1919, the attention of this Department was called to the stem-rot and wilt of tomatoes growing in the College greenhouses. Out of 90 plants 85 showed lesions of greater or less extent on the stems and as the disease progressed many of the affected plants wilted above the point of infection. By February 20 fully 50 per cent of the diseased plants had wilted.

SYMPTOMS OF THE DISEASE

The first symptom of trouble is the appearance of gray, slightly sunken spots on the stems, often beginning about an old leaf scar as a center (fig. 1). The lesion enlarges slowly and after five or six weeks may extend over a section of the stem 6 inches long, extending nearly around it.

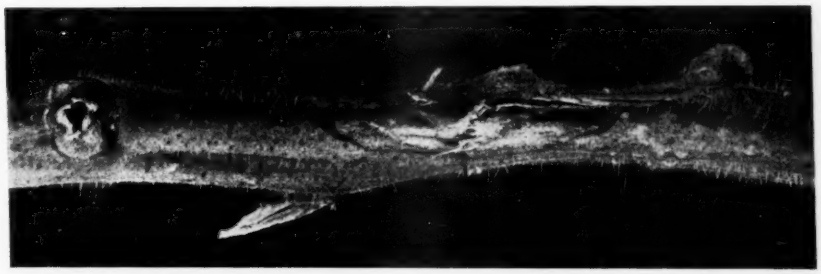


FIG. 1. PORTION OF A TOMATO STEM SHOWING LARGE LESION, ALSO A SMALL LESION BEGINNING AT AN OLD LEAF SCAR

As the lesion continues to enlarge, the stem is girdled and the upper part of the plant wilts. In most cases the stems bore only one or two lesions and these were about a foot above the surface of the soil. Occasionally a lesion was found higher up on the stalk. Upon sectioning the stems it was found that the rot penetrated the pith, involving the cortex, vascular ring and medulla. The vascular bundles were discolored slightly but the browning did not extend appreciably above or below the lesion.

CAUSAL ORGANISM

If a section of diseased stem be placed in a moist chamber the edges of the lesion take on a water-soaked appearance within twenty-four hours. At the end of thirty-six hours a gray fungus growth is noted about the margins (fig. 2). This fungus is a species of Botrytis. After four days this fungus growth becomes very prominent, and conidiophores also appear on the older parts of the lesion.

FIG. 2. DISEASED STEM AFTER THIRTY-SIX HOURS IN A MOIST CHAMBER SHOWING GROWTH OF *Botrytis sp.* AROUND EDGES OF THE LESION

CULTURES

February 8 dilution cultures were made from the fungus appearing around a lesion. Also some tissue was taken and planted in nutrient agar. Out of twenty-one plates made all gave practically pure cultures of *Botrytis sp.* The cultures began to fruit on February 18. The fungus was first a very light gray or nearly white, later becoming a dark, dirty gray. Up to the present time (March 27) no sclerotia have been formed in culture nor have they been found in diseased stems.

INOCULATIONS

February 12 healthy stems were inoculated with pure culture by stabbing. The wounds healed slowly and abnormally but the fungus did not become established. The check plants remained healthy.

Ten plants were sprayed with a suspension of spores. These plants remained healthy.

February 19, healthy stems were inoculated with pure culture by stabbing and wrapping the wounds with wet cotton. February 24 lesions appeared around the wounds and slowly spread until on March 1 they were an inch in diameter. These diseased stems were placed in a moist chamber. The next day the lesions showed the water-soaked margins and in two days *Botrytis sp.* appeared in pure stand from which were obtained pure cultures showing all the characters of the original inoculum. Check plants similarly wounded and wrapped in wet cotton healed normally.

A vigorously growing plant was placed under a bell jar and inoculated by stabbing with pure culture. February 24, well marked lesions occurred around the wounds. By March 1 these involved the whole circumference of the stem, producing a copious growth of *Botrytis sp.*

Under these excessively humid conditions the fungus spread to the leaves causing them to rot. Check plants similarly grown remained healthy.

Cultures of the organism have been sent to Prof. H. H. Whetzel of Cornell University, but as yet the species has not been determined.

IMPORTANCE

Since infection takes place only under exceptionally humid conditions it is not thought that the disease will become of very great importance where greenhouses are properly ventilated. However, in regions where there is cloudy, damp weather for weeks at a time, such as is common here in November and December, the disease may cause considerable loss.

BOTANICAL DEPARTMENT,
ONTARIO AGRICULTURAL COLLEGE,
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HARVEY ELMER VASEY

E. MEAD WILCOX

WITH PORTRAIT

Harvey Elmer Vasey was born at Holmesville, Nebraska, February 6, 1890, and died at Fort Collins, Colorado, December 10, 1918. Following his graduation from the high school at Liberty, Nebraska, he entered the University of Nebraska in 1908 and received the B.Sc. degree in 1913. The following year he was granted the A.M. degree for work in plant pathology. From 1913 to 1916 he was officially connected with the department of plant pathology of his alma mater and from 1916 to the time of his death he was engaged in similar work in the State Agricultural College of Colorado. During the summer of 1916 Vasey did graduate work in botany in the University of Chicago.

Vasey was selected by his institution during the summer of 1918 to enter the Officers' Training School at the Presidio, California to qualify

for work in connection with the S. A. T. C. unit to be established at Fort Collins. He was commissioned first lieutenant and at once took up his duties at Fort Collins. His knowledge of the institution and his personal knowledge of the faculty and the students rendered his military work highly successful. His death from pneumonia following an attack of influenza occurred while he was actively engaged in the demobilization of his unit. His characteristic devotion to his work, even to the neglect of his own health, was no doubt an important factor contributing to his untimely death.

While at the University of Nebraska, Vasey had experience in research, teaching and extension and in all three lines showed marked ability. The highest type of intellectual honesty and frankness characterized his every relation to his instructors, his students and the people who came to him for the solution of their practical problems of plant disease control. To render genuine service, without consideration of either financial reward or personal glory, was his ambition. He laid broad foundations for a career of the greatest usefulness. His paper on "Millet Smuts and Their Control" published as Bulletin 242 of the Colorado Experiment Station was his most important contribution to the literature of plant pathology.

To those who knew him, Vasey will ever be remembered as a true friend and a splendid example of manhood. He gave his life to his country, and to his friends he left the remembrance of his cheery optimism and his high ideals of service. Perhaps the following sentiment best expresses his guiding ambition:

"There are hermit souls that live withdrawn
In the place of their self-content;
There are souls like stars, that dwell apart,
In a fellowless firmament;
There are pioneer souls that blaze their paths
Where highways never ran—
But let me live by the side of the road
And be a friend to man."

PHYTOPATHOLOGICAL NOTES

The influence of soil temperature on potato scab. Experimental work now under way in the department of plant pathology at the University of Wisconsin indicates that high soil temperature is a factor favoring the development of potato scab. Since the parasite, *Actinomyces scabies,* belongs to a high temperature group this is what we might expect, but there is, nevertheless, no agreement shown in published records as to the relation of soil temperature to the occurrence of the disease. Our experimental results are, however, so well in harmony with certain personal observations that we incline to think that this failure to recognise the relation heretofore has been in part due to the complicating influence of other variable factors and in part to the lack of a clear definition of the questions involved, such as whether the most influential factors are those controlling infections in the earlier stages of tuber formation or those operating during the subsequent development.

It is nearly fifteen years since the senior author observed that potato scab was not as seriously prevalent in northern European fields as it is in America.[1] His conclusion then reached was that this must be due to climatic differences, since the other recognized factors, such as moisture, soil reaction, or manure, must vary in much the same way in Europe as in America. It was further noted that rotation, considered as essential for guarding against scab in America, is not so recognized in Europe, potatoes often being grown continuously for many years there on highly fertilized soils without the development of scab. The climatic difference between the potato growing sections of northern Europe and America is, of course, the absence there of our period of mid-summer high temperature, which may carry our soils to high temperatures during the "critical period"[2] of the potato's development.

In Wisconsin our general observations indicate a greater prevalence of scab in the warmer regions than in those where cool summer temperatures prevail, e.g., in the north end of Door County peninsula, which is practically surrounded by cool waters. Morse's observations that scab is not regarded as a serious factor by the Aroostook potato growers of northern

[1] Jones, L. R. Diseases resistance in potatoes. U. S. Dept. of Agr., Bur. Pl. Ind. Bul. 87. 1905.

[2] Jones, L. R. The diseases of the potato in relation to its development. Mass. Hort. Soc. Trans. **1903**, pt. I: 144–154.

Maine may be noted in this connection. The potato disease surveys of Wisconsin show 1916 to be the worst of recent "scab years" and this was also notable as one of the hottest summers ever recorded by the U. S. Weather Bureau. The difficulty of properly weighing all the variable factors concerned with such a disease as potato scab would keep us from interpreting these observations with such confidence were they not in accord with our recent data secured in greenhouse experiments. We are now expecting to secure more accurate field data by experimental methods this summer. Meanwhile we are publishing this note in the hope that it may stimulate others who have opportunity to commence any pertinent observations. This is especially to be sought in those southern states where two crops of potatoes are grown, one during the cooler, the other during the warmer season. In the northern states similar evidence may possibly be had where early and late plantings of the same variety are grown alongside each other on scab-infested soil. The writers will welcome any pertinent suggestions from correspondence, whether based on previous experience or that of this summer.

L. R. JONES AND H. H. MCKINNEY.

Agricultural Index. The H. W. Wilson Company, New York City, publishers of the "Agricultural Index," a current cumulative indexing service issued ten times a year, have just published a three-year cumulation for 1916–1918. The volume contains 1056 pages with 70,752 references. In a single volume, somewhat larger than the "Student's Standard Dictionary," it affords a permanent record, by subject, of the articles in a selected list of seventy-eight periodicals of the United States and ten foreign countries, including farm papers and technical journals, also the publications of agricultural experiment stations, state and federal departments and boards, the reports of agricultural and historical associations, and the extension bulletins of colleges and universities. The entries are arranged in alphabetical order like a dictionary, each article is entered under as many subject headings as the contents demand, and many cross references are used.

Personals. Mr. Glen B. Ramsey, assistant pathologist, Bureau of Plant Industry, has been transferred recently from Orono, Maine, where he had charge of extension work on the control of truck crop diseases, to Chicago, Ill., where he will be engaged in work on the identification of diseases of market vegetables.

Dr. Forest E. Kempton, who graduated from the University of Illinois last spring and was employed during a part of the past year as plant pathologist of the Porto Rico Agricultural Experiment Station, has ac-

cepted an appointment in the Office of Cereal Investigations, Department of Agriculture as assistant state leader in barberry eradication work. He is located at the University of Illinois, Urbana.

Mr. Hugo W. Albertz of the University of Wisconsin has been appointed an agent of the Bureau of Plant Industry and stationed at Madison, Wis. He will study the Fusarium rot of corn, with special reference to breeding and selecting for resistance.

Mr. Benjamin H. Duddleston of the University of Wisconsin has been appointed assistant pathologist in cereal investigations, U. S. Department of Agriculture, and is engaged in investigations of Fusarium rots of corn, at the Indiana Agricultural Experiment Station, LaFayette.

Mr. Eugene D. Holden of the University of Wisconsin has recently been released from military service and has accepted a position as agent in the Bureau of Plant Industry. He will assist in research investigations on the stripe diseases of barley and ergot of rye, in cooperation with the University of Wisconsin, and will be stationed at Madison.

Mr. R. W. Leukel, recently principal and teacher of science at the Waunakee High School, Waunakee, Wisconsin, has been appointed field assistant in cereal investigations, Bureau of Plant Industry, to assist in investigations of the nematode or eelworm disease of wheat. He will be stationed at Washington, D. C.

Mr. Harold H. McKinney, who was a field assistant in the barberry eradication work of the U. S. Department of Agriculture during the summer of 1918, has been re-employed by the Department as an agent and will undertake research on Helminthosporium diseases of barley, ergot of rye, and Septoria of cereals, at Madison, Wisconsin.

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[1] This list includes references, both American and foreign, to the literature of plant pathology and mycology of interest to pathologists. Foreign references published since January 1, 1917, have been included beginning with the list appearing in v. 7, no. 3, June, 1917.

All authors are urged to cooperate in making the list complete by sending their separates and by making corrections and additions, and especially by calling attention to meritorious articles published outside of regular journals. Reprints or correspondence should be addressed to Miss E. R. Oberly, Librarian, Bureau of Plant Industry, U. S. Dept. of Agric., Washington, D. C.

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